

Recent developments of historical climatology in Central, Eastern, and Southern Europe

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Historical climatology is a rapidly developing interdisciplinary field in Central, Eastern, and Southern Europe, transforming qualitative weather-related descriptions as well as phenological and physical data from documentary sources to quantitative high-resolution climate reconstructions, thus allowing for the study of the impacts of climate variability on society.

Among paleoclimate proxies, the transformation of descriptive qualitative information and documentary evidence to quantitative data (see e.g. Pfister and Brázdil 1999) has provided the highest resolution information for the reconstruction of temperature, precipitation, and other weather-related extremes over the last 500 years. Even if the time period covered is often shorter than that of most climate proxies, reconstructions may cover every month of a year. To date, Central and Southern Europe hold the largest documentary-based flood and drought collections as well as the most comprehensive and longest (index-based) local-regional temperature and precipitation reconstructions, and have played a key role in investigations where all major regions of Europe were represented (e.g. Brázdil et al. 2018; Blöschl et al. 2020). As for timescale, the temporally densest (often daily) documentation is available from Central and Southern Europe for the last 200–300 years; monthly seasonal data can be gathered for the last 400–500 years. Occasionally, representative data may cover ca. 700–800 years; however, regarding weather-related extreme events, documentary evidence in certain areas of Southern Europe may cover a period over the last two millennia or more (Camuffo and Enzi 1996).

Southern Europe

In Southern Europe, the reconstruction of hydroclimatic extremes, i.e. droughts and floods, on a multi-centennial scale is currently a large focus within flood and drought databases, sometimes reaching back two millennia. Major source types applied are narratives (esp. chronicles), church and municipal legal and economic administrative documentation, and, to a lesser extent, private and official correspondence and newspapers. Most research is concentrated on the Iberian Peninsula and Italy.

Research on the Iberian Peninsula concentrates particularly on flood- and drought-severity reconstructions over the last ca. 700 years (e.g. Oliva et al. 2018; Barriendos et al. 2019). While early research mainly draws upon municipal legal and economic records, later research primarily focuses upon rogation ceremonies, a complex social demonstration of droughts systematically preserved in the administrative sources of municipal and ecclesiastical institutions. Despite significant results in Spain and Portugal, documentary evidence still holds immense further potential; to date, only

around 4% of historical sources have been exploited by historical climate research. From the Iberian Peninsula, continuous early instrumental measurement series date back to the mid-/late 18th century; Italy holds the earliest systematically measured daily series of temperature and precipitation dating back to 1654 and 1713, respectively. Except for a 500-year rainfall reconstruction of the Iberian Peninsula, mostly individual-local and no regional-scale temperature or precipitation index reconstructions exist in Southern Europe (Camuffo et al. 2010). Southeast Europe, apart from the grand collection of medieval Byzantine weather reports (e.g. Telelis 2008) and occasional individual publications, remains underrepresented in systematic research. Besides the reconstructions of hydroclimatic extremes, long-term socio-economic impacts of changing weather conditions and weather-related extremes, especially droughts, also play a rather important role in Southern Europe (e.g. Gil-Guirado et al. 2016).

Central Europe

Central Europe is perhaps the most intensively involved area in historical climatology research within Europe. With a few gaps, index-based reconstructions of temperature, precipitation, and/or weather-related extreme events (e.g. floods, droughts, and windstorms) are available from most parts of Central Europe for the last 500 years or millennium (e.g. Glaser 2013; Brázdil et al. 2016). This is the only area of Europe where

a complete regional monthly-resolution (index-based) 500-year temperature reconstruction is available: the Central European reconstruction (Dobrovolný et al. 2010), developed within the framework of the Millennium project (2006–2010), was published together with its other results as a historical climatology special issue of the journal *Climatic Change* (vol. 101, 2010). The annual resolution spring-summer temperature over the last 400–500 years were also published from most countries of Central Europe including Switzerland, the Czech Republic, Germany, Austria, and Hungary, in some cases accompanied by precipitation reconstructions. These were based on systematic daily resolution information on vine and grain phenophasis dates, such as blossoming, ripening, and grain and grape harvesting.

In Central Europe, from the Middle Ages onwards, the key source types applied are narratives (e.g. annals, chronicles, and diaries), official and private correspondence including newspapers, and partly systematic economic and legal administrative documentation (municipal accounts, council minutes, charters, accounts, and taxation records). Except for those countries with systematic historical climate research, such as the Czech Republic, Switzerland, and Germany, the latter two source types, together with specialized agricultural, weather and phenological diaries, and early instrumental records (from the early/mid-18th century) and daily weather observations, are



Figure 1: Examples of types of sources applied in reconstructions. For details, see the online version of this article.

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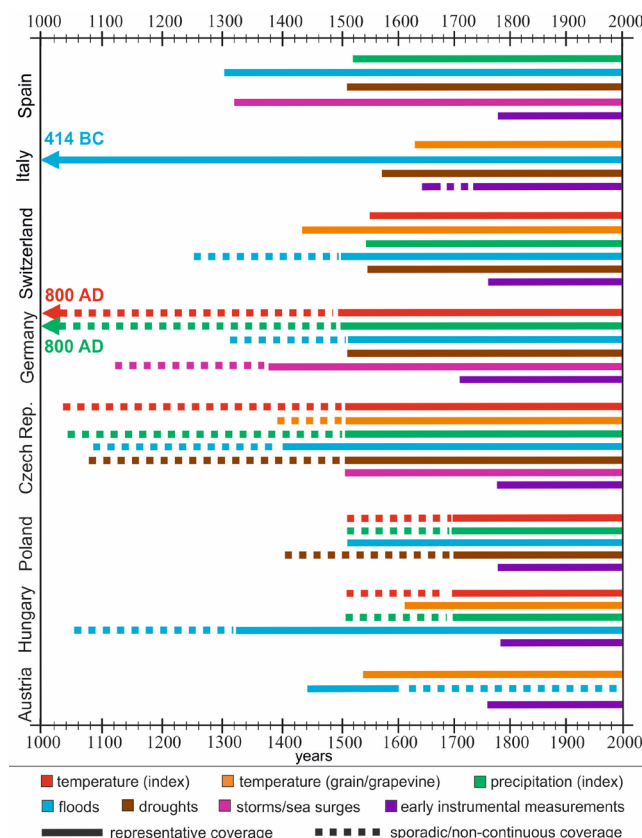


Figure 2: Long-term documentary-based flood, drought, storm, and monthly or seasonal temperature and precipitation reconstructions and grain- or grapevine-based temperature reconstruction series in Central, Southern, and Eastern Europe by country.

still to a large extent unexplored, and hold immense potential for further high-resolution multi-centennial reconstructions in the rest of Central Europe.

A further important research area is historical impact analysis of individual catastrophic weather and hydroclimatic events, anomalous periods, or long-term interactions and processes (e.g. Camenisch et al. 2016). In recent years, the attribution of major food shortages in historical times to severe weather conditions, as well as the climatic and socio-economic impacts of major volcanic eruptions in Central Europe, particularly the Tambora eruption and the Year Without a Summer, in 1816, have attracted further attention (e.g. Luterbacher and Pfister 2015).

Eastern Europe

In Eastern Europe, including Russia, the Baltic countries, Belarus, Ukraine, and Moldova, climate-history research is currently based on narrative sources, in particular chronicles and annals. Temperature, precipitation, and extreme-event reconstructions, derived from data in the major northern Russian chronicles and annals that cover most parts of the last millennium, have been carried out by Borisenkov and Pasetkiy (2002). This work has been criticized by some for the source interpretation methods used. The medieval part of this work was updated and summarized by Klimenko and Solomina (2010) in a volume discussing the historical climatology of the Polish-Lithuanian Commonwealth.

Early instrumental measurements and professional daily observations extending back to at least the mid-18th century have

only been partially explored. No investigations have been carried out, so far, using other source types such as systematic legal administrative documentation, or economic sources such as accounts at the municipal, estate, district, regional, and country level; this documentation still holds great potential in Eastern Europe.

Recent highlights

While in previous decades, long-term temperature and precipitation reconstructions and early instrumental measurements were the main priority, in recent years, individual extremes and the long-term reconstruction of hydroclimatic extremes have received greater attention. Aside from individual flood and drought reconstruction papers, European and global-scale special issues on historical floods ("Floods and their changes in historical times" in *Hydrology and Earth System Sciences*: 2015-2016) and droughts ("Droughts over centuries" in *Climate of the Past*: 2019-2020, "Societal impacts of historical droughts" in *Regional Environmental Change*: 2019-2020) contain dozens of studies with new, multi-centennial reconstructions, particularly from Central and Southern Europe. Furthermore, with particular attention paid to Central and Southern Europe, regional and continental-scale online databases have been developed in the last decade(s) and opened for public use in recent years (e.g. Euro-Climhist, Tambora).

A research direction that is rapidly growing in importance is climate history that deals with the impacts of weather and weather-related extremes on the human environment, human responses on these impacts and consequent socio-economic processes, and

the short- and long-term socio-economic consequences of climate variability including the complex interaction between climate and the human environment. Beyond the early modern case studies focussing on regional or European climatic extremes, there is currently a strong emphasis on the impacts of weather in anomalous periods of the (late) Middle Ages, the Late Medieval-early modern Period, and the transition from the Medieval Warm Period to the Little Ice Age, with special emphasis on Southern and Central Europe (e.g. Kiss and Pribyl 2020).

Despite intensive work over the last three decades, historical climatology and climate history are still developing fields with great further potential as, to a regionally varying extent, a large part of the documentary evidence is not yet explored. This is particularly true for Eastern and Southeast Europe, but even most areas of Central and Southern Europe still offer numerous further possibilities for future historical climatological research.

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